

# LOW COST FOREST OPERATION SYSTEMS FOR MIXED SPECIES MANAGEMENT

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**Abstract**—This is a summary paper about the development of forest operation systems for regenerating mixed-pine and hardwood stands that reduce costs and environmental impacts by working more in concert with natural successional trends. The environmental impacts focus on protecting site productivity, primarily through reducing the impacts of forest operations on post-harvest soil movement. The cost savings result from not spending resources on trying to eradicate the hardwood component that develops naturally over time on these kinds of sites. The primary operations involve clearcutting the merchantable stand, felling the residual trees, implementing post-harvest site preparation burns, and planting pine seedlings at wide spacings among the hardwood regrowth. *Timing of the residual felling affects fuel structure and subsequent intensity and uniformity of the post-harvest fire.* A key step in protecting against excessive soil movement is to not consume the forest floor with the fire. As forest floor is reduced, soil movement increases. Timing of the residual felling also affects post-harvest fire behavior, early vegetative development of the hardwood regeneration, and small mammal population dynamics. We have results from a preliminary investigation into the interrelations that forest operations have with landform and edaphic properties of site. It links vegetative response to land units defined and delimited by an ecological classification system. This classification system uses landform and edaphic variables to predict the range of seral plant-community development to expect on a particular parcel of land. Preliminary results from a case study show how ecological units can respond differently when treated similarly.

## INTRODUCTION

Seventy-five percent of the forest land base in the Piedmont region of the Southern United States is controlled by nonindustrial private forest (NIPF) landowners. The NIPF land base is large, but individual holdings are on the average small, which means that the number of landowners is large. The landholders own land for many different reasons, so it stands to reason that they have widely varying land-use objectives. A major disincentive for these landowners to practice good forest management is low unit value for stumpage due to an overabundance of low-quality timber and the risks associated with the long-term nature of forestry investments. The consequence of these disincentives is a harvest-only management approach that removes marketable trees and leaves behind low-quality residual trees. The larger, low-quality residual trees disproportionately capture the site because of their size advantage relative to the regeneration that results from the harvest activities. This produces a negatively reinforcing cycle of increasingly poor-quality trees, and further erosion of the incentive for investing in higher future timber yields.

*Industrial assistance programs for NIPF landowners, and government supported cost-share incentives have helped put some of these lands into productive pine plantations, but this effort is small relative to the magnitude of the problem. Furthermore, the objectives of pine plantation management are often too narrow for NIPF landowners, and the public incentive dollars used to create the plantations are becoming increasingly difficult to justify as tax dollar expenditures. Pine plantation establishment procedures are designed to reduce or temporarily eliminate the hardwood component that develops naturally in Piedmont stands, but these kinds of activities extract a high cost in terms of energy used and productivity lost through soil disturbance and nutrient loss from the site. The end*

result of these constraints is that a high percentage of the 21 million-acre NIPF land base is being stocked with timber of low quality and/or lower than optimal density.

The guiding hypothesis for our overall research program has been that low-quality, mixed-species stands like those developing naturally on much of the NIPF land base can be cost-effectively managed for improved timber production as mixed southern yellow pine and hardwood stands. Naturally regenerated, largely low-quality, mixtures of pines and hardwoods are presently found on about one quarter (or about 7.1 million acres) of the total Piedmont commercial forest. This research has focused on how understanding the disturbance patterns and post-disturbance species composition responses that produce these pine-hardwood stands can be used to develop forest operation systems that work with nature. The result is operations that produce good-quality, well-stocked, pine-hardwood mixtures at less investment cost, with less impact to the site, and which meet a wider range of land management objectives than does the proven pine plantation system.

*This paper does not report the results from a single study, with the usual detailed descriptions of the experimental design, methods, and results. Rather, it summarizes most of the literature that the USDA Forest Service and other research institutions have reported about pine-hardwood regeneration dynamics in the Piedmont physiographic region, and the implications these biological responses have on forest operation systems. The first group of studies deals with quantifying the effects of several forest operation scenarios on pine-hardwood regeneration dynamics and site productivity. We conclude by examining what a case study has to suggest about the potential role of ecological land classification on forest operation prescriptions, or specifically: how ecological units can be used to relate*

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vegetative response to forest operations using spatial measures of landform and soil attributes.

## FOREST OPERATIONS FOR ESTABLISHING PINE-HARDWOOD MIXTURES

The rapid initial height growth of hardwood coppice relative to pines from seed or planted seedlings has been a source of concern to managers and researchers interested in establishing pine when hardwood competition is not controlled. As a result, initial research emphasis was on cost-effective means of controlling hardwood regeneration long enough to allow the shade-intolerant pines to become established as a component of the overstory canopy. McGee (1986, 1989) reported high survival and rapid growth of planted loblolly pines (*Pinus taeda* L.) after harvesting low-quality hardwood stands by chainsaw to a 4-inch lower diameter limit (with and without herbicide injection of residuals) and by shearing to a 1-inch limit. Lloyd and others (1991) showed for the Appalachian foothills region of South Carolina that diameter growth of shortleaf pines (*P. echinata* Mill.) in pine-hardwood mixtures improved after release at age 4, but that release was not necessary to assure survival. In a study by McMinn (1989), naturally regenerated shortleaf, virginia (*P. virginiana* Mill.), and loblolly pines were largely absent from areas harvested in the growing season and were suppressed in dormant-season commercial clearcuts that left large (relative to regeneration) residual trees.

Much of our research on hardwood control has centered on a set of operations described by Abercrombie and Sims (1986) which proved successful in the Southern Appalachian Mountains (Phillips and Abercrombie 1987). The technique includes a commercial clearcut followed by spring felling of residual hardwood stems (> 2 meters in height) and a summer broadcast burn. Felling and burning are designed to control hardwood sprout growth so pines can be established without eliminating hardwoods. Pines are planted the following winter at a wide spacing (15 by 15 feet or more) to reduce costs and to avoid early canopy closure of the pines over the hardwood, thus insuring that some hardwoods will receive direct light from above, and thus contribute significantly to merchantable stand growth.

Site preparation burning is an attractive operation for pine-hardwood regeneration in the mountains for several reasons. Burning is less expensive than mechanical site preparation and, if done properly, has less environmental impact. By burning in July, as suggested by Abercrombie and Sims (1986), hardwood sprouts are top-killed and new sprouts that emerge after burning have a shortened growing season. These new sprouts remain shorter than sprouts in unburned stands for 4 years or more, allowing pines a better chance to survive (Waldrop 1995). Sprout quality is improved by burning because stump sprouts are replaced by well-anchored basal or root sprouts (Augspurger and others 1989). Site preparation burning proved to be particularly attractive in areas with heavy coverage of mountain laurel (*Kalmia latifolia* L.) that would be too expensive to regenerate using mechanical control (Williams and Waldrop 1995).

Early trials of pine-hardwood regeneration in the Piedmont suggested that site preparation burning might be too risky (Waldrop and others 1989). In this region, forest floor thickness varies by site, but remains substantially thinner than in the mountains (Ball and others 1993). Therefore, the danger of exposing soil to erosion by consuming the forest floor organic layer is much greater in the Piedmont. For example, Van Lear and Kapeluck (1989) reported the loss of over 1.5 inches of topsoil during a 9-month period after burning a Piedmont site that had been subjected to an extended dry period prior to the rain event that prompted the burn. Other than the weather conditions prior to the burns, the burning prescription used in that study was identical to one used in a previous study in the Appalachian foothills region in South Carolina (Van Lear and Danielovich 1988) where burning caused no increase in erosion. In this Piedmont experiment, the rainfall events that prompted the burn were insufficient to break the preceding drought, thus allowing the fire to totally consume the forest floor. This, coupled with the thinner organic layer characteristic of the Piedmont, resulted in damaging results.

Several studies are being conducted to learn how to use site preparation burning without causing erosion. Robichaud and Waldrop (1994) burned adjacent mountain sites using burning prescriptions that created conditions of low- and high-severity fire impacts (with regard to soil exposure). Low-severity burns were conducted 6 days after a 4-day rainfall event totaling 1.5 inches. For this burn, the moisture content of the litter layer was 65.2 percent. High-severity burns were conducted 14 days after a rainfall of 1.7 inches and with the moisture content of the litter layer at only 5.9 percent. Sediment loss for one year after burning totaled 2.33 tons per acre from the high-severity burns, but only 0.06 tons per acre from the low-severity burn (Stone and others 1995). Site productivity was reduced by high-severity burning with biomass production being two times greater in the low-severity sites (0.32 vs. 0.68 tons per acre). Even though high-severity burning reduced site quality, pine survival was significantly higher in the high-severity burn areas (77 percent in the high-severity area versus 58 percent in the low-severity). This result was attributed to increased vegetative competition on the low-severity sites.

Fire severity is also related to another operation used to establish pine-hardwood mixtures: the felling of residual hardwood stems. Residual stems are supposed to be felled by chainsaw crews during the spring when new leaves are almost fully developed. Broadcast burns are conducted 4 to 6 weeks after the stems are felled, generally in mid-July to early August. By that time, the fine woody fuels are dried sufficiently to burn intensely. Waldrop (1995) showed how fire behavior and fire severity is controllable by varying the season of the residual-stem felling. By felling during winter, foliage was not present. Therefore, the easily ignited leaf litter was limited to that found on the forest floor, and if burning conditions are as they should be, this material will be relatively moist and will not burn well, thus making it difficult to get the fire to carry between areas of accumulated slash. In spring-felled areas, dry leaves left on

the felled residuals carried the fire, producing uniform burns across the entire study area, while winter felling produced a patchy burn pattern. The patchy burns for the winter felling operation may help meet some objectives by increasing early-successional plant and animal species diversity (Evans and others 1991) and contributing to early stand structural diversity by leaving more woody debris. Also, winter felling may reduce erosion by decreasing burn severity and leaving more debris dams; however, this effect has not been studied.

Even though winter felling may reduce erosion, it may not control hardwood competition as well as felling in spring. Phillips and Abercrombie (1987) suggested that spring felling would better control hardwood sprout growth than winter felling because spring felling is conducted when carbohydrate reserves in root systems have been exhausted by the early season growth initiation. Geisinger and others (1989) found that hardwood sprouts in the Piedmont region were shorter in spring-felled areas than in winter-felled areas after one growing season. However, by the end of six growing seasons the winter felling of residual stems, followed by a summer site preparation burn, had produced nearly identical stands to those regenerated by spring felling and summer burning (Waldrop 1997). Growth reductions from spring felling lasted only one growing season and had no apparent effect on stand development. This result suggests that the precise timing of felling as described by Phillips and Abercrombie (1986) is not as critical for the Piedmont ecosystem.

Several studies of regeneration techniques in the Piedmont suggest that little or no site preparation is needed to establish pine-hardwood mixtures on the medium-to-dry sites. Waldrop (1991) and Perry and Waldrop (1993) report on a study that harvested small groups in 0.10- and 0.33-acre openings, in a merchantable-sized hardwood stand, with the long-term goal of creating multi-aged, pine-hardwood stands. They found that edge trees reduced hardwood height growth in the opening more than that of planted loblolly pines. This pattern allowed the pines to overtop hardwoods within 2 years with no site preparation. In another study involving clearcutting the entire stand, Waldrop (1997) found that site preparation burning did not improve the survival or growth of planted loblolly pines. Pines overtopped hardwoods in burned areas by age 4 and in unburned areas by age 6 (fig. 1).

We know that hardwood regeneration is more abundant and faster growing on high productivity sites, so crown closure could occur on these better sites before pines reach the upper canopy. Additional research is needed to identify the kinds of sites where forest operation systems designed to regenerate pine-hardwood mixtures will work. Ecological land classification might have a role to play in improving these kinds of decisions.

## USING ECOLOGICAL CLASSIFICATION IN PLANNING FOREST OPERATIONS

Pine-hardwood regeneration research in the Piedmont physiographic region has focused so far on the dryer-than-

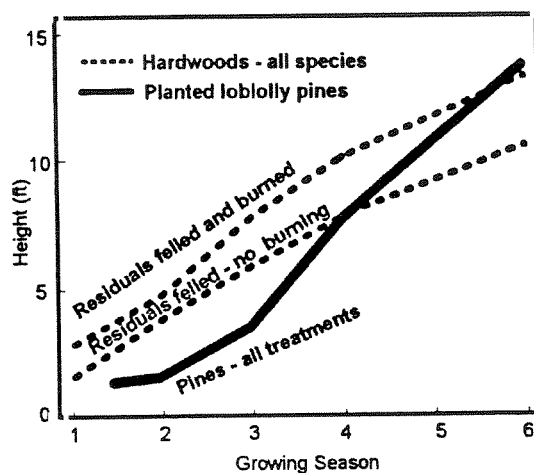


Figure 1—Mean height of natural hardwood regeneration (by site preparation treatment) and planted loblolly pines (all treatments combined) for 6 years after harvest.

average sites. These results on dry sites suggest that little more than felling the non-merchantable residuals and planting pine with wide spacing is needed to get a productive pine-hardwood mixture. However, it is well known that hardwood coppice and advanced seedling regeneration will outgrow pine seedlings on the better sites. In the upland forest of the Piedmont region, an important productivity gradient is due to increasing soil moisture availability. Hardwoods are not only more sensitive to site productivity than pines, but they are also more abundant on the better sites. If we had a practical way to model moisture gradients, we might be able to tailor harvesting prescriptions to site conditions. Jones (1991) has developed a promising model of land classification for the Piedmont region that appears to capture a meaningful ecological gradient that has potential for helping tailor forest operation prescriptions.

A lot of soil-site research has tried, with very limited success, to develop predictor equations of site productivity using only a few key variables. Jones' (1991) approach recognizes the inherent difficulty in identifying a few predictor variables that will reliably quantify an ecologically meaningful gradient. In most cases, the gradients to which plants respond are very complex, involving the interplay of numerous variables, many of which we do not even know about. His approach is to let the plants do the integration of variables for us through the patterns of species birth, growth, and death that produce the range of plant communities we find developing on a site over time. Specifically, he investigates the presence and absence of plant species on reference sites, where reference sites are areas that have no signs of major species-eradicating disturbances. Classification methods are used to organize and present the results through the use of the relationship that species presence and absence has with spatially oriented landform, and edaphic variables. The spatial (or map oriented) nature of the landform and edaphic variables

are then used to identify and delimit ecologically equivalent land units.

These spatially explicit, vegetation-derived, landform/edaphic relationships are then used to delimit land units independent of vegetative cover presently on the land. This approach provides a way to sort out and categorize the wide array of seral communities that can occur across an entire region. The hypothesis is that the range of seral community development within ecological classes will be less than the range of seral communities encountered across all site units. This approach has provided an easy-to-use land classification format useful in organizing what experienced foresters learn intuitively from field observations about site and plant community relationships. We see potential for using the ecological classification to predict species compositional dynamics that follow specific forest operations on specific land units.

Although the pine-hardwood regeneration study reported by Waldrop (1997) was not designed to investigate the potential of Jones' model in aiding forest operation prescriptions, it did contain three site unit types (submesic, intermediate, and subxeric) within one treatment area. Guidelines in effect at the time the regeneration study was installed said that pine-hardwood regeneration should be restricted to south-facing slopes. This resulted in all plots in the regeneration study being located on subxeric ecological land classification units. At stand age 6, we installed four additional plots on the intermediate and submesic land units in one of the treatment areas of his study (two plots in each ecological unit), and compared the results with those on the subxeric units in the original study design. The results are presented in tables 1-3.

Table 1 shows that there is a dramatic change in hardwood stocking in terms of numbers of stems (greater than 6 feet tall) per acre between the submesic versus the intermediate and subxeric land units. Although pines (planted and naturally regenerated from seed) are present on all ecological units, table 2 shows pines making up only 15 percent of the total basal area on the submesic land units, compared to 45 and 46 percent, respectively, for intermediate and subxeric units. This is in spite of the fact that the numbers of pines are also much larger on the submesic site unit because of a large number of volunteers seeded in from an adjacent pine stand. Most of these volunteer pines will die from being overtopped by the vigorous hardwood regeneration. The planted pine

Table 1—Hardwood stocking by ecological unit

Unit	Stems	Basal area
	No./acre	Ft <sup>2</sup> /acre
Subxeric	760	6.8
Intermediate	920	5.6
Submesic	2960	16.8

Table 2—Planted pine stocking by ecological unit

Unit	Stems	Basal area	Survival
	No./acre	-----Percent-----	
Subxeric	140	46	72
Intermediate	130	45	76
Submesic	100	15	52

Table 3—Heights of dominant hardwoods and pines

Unit	Hardwoods	Pines
	-----Feet-----	
Subxeric	12.1	17.0
Intermediate	14.1	17.7
Submesic	16.4	15.4

component on the submesic unit appears to have sufficient height to become a viable part of the mature stand; however, these pines are smaller in diameter and height than the corresponding set of planted pines on the intermediate and subxeric land units.

Since the goal is to develop pine-hardwood mixtures, the 6-year, average cumulative height growth of dominant oaks and pines is presented in table 3. "Dominant" means the tallest hardwoods at a density (numbers per acre) equivalent to the pine planting density. The hardwoods display the expected growth patterns of increasing average height to increasing site quality represented by the ecological land units. The lower total height of pine on the submesic area (15.7 feet on the submesic compare to an average of 17.4 feet on the intermediate and subxeric units) is attributed to hardwood competition effects. A further indication of the hardwood competitive effect is that at age 6 on the submesic unit, the tallest hardwoods averaged a foot taller than the pines. Although it cannot be determined from this study, the results raise the question of whether the pines would have survived at all without the summer fire treatment that set back the initial hardwood growth response. These results offer a working hypothesis that this kind of ecological land classification system has potential for tailoring our forest operation prescriptions to the land. Further research is needed to fully test this hypothesis.

## CONCLUSIONS

These studies suggest that forest operations designed to develop pine-hardwood mixtures can produce productive timber stands and diverse plant communities at a lower cost and with less degradation to site quality than the intensively site prepared, pine plantation system. Mixed pine-hardwood stands meet a wider array of land

management objectives and require less costly (both environmentally and economically) forest operations. The resulting pine-hardwood forest operation systems are well suited to the economic conditions and land management needs of many NIPF landowners.

Ecological classification offers a tool for transferring research results to the particular management application, and a way to tailor forest operations within stands. Although results are preliminary, indications are that without the use of a post-harvest site preparation fire, pine-hardwood management in the Piedmont will not work better on ecological site units than intermediate, that is, the mesic and submesic land units of Jones' model. Although mesic and submesic ecological land units are scarce in the Piedmont relative to the area composed of intermediate and subseric land units, they nevertheless are productive pine-hardwood sites suitable for sawtimber management, in which case post-harvest fire would likely be needed to get a pine component established.

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